Jet Propulsion Laboratory
California Institute of Technology

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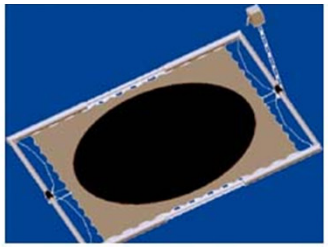
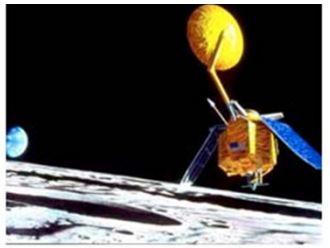
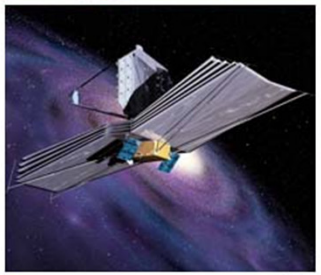
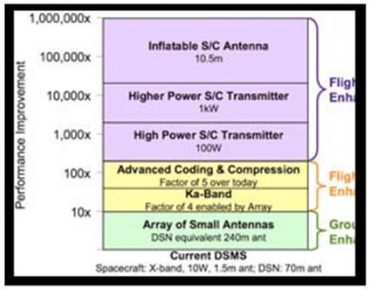
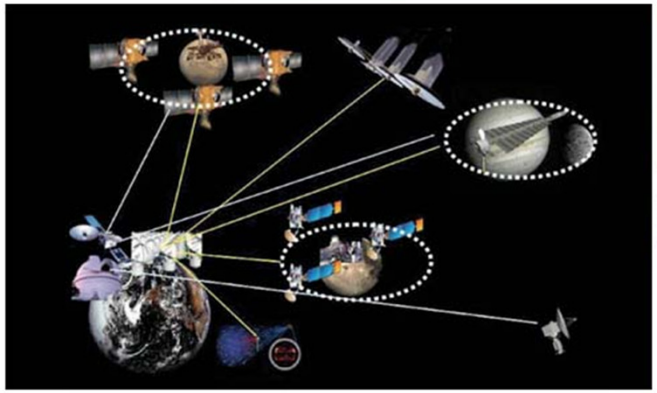
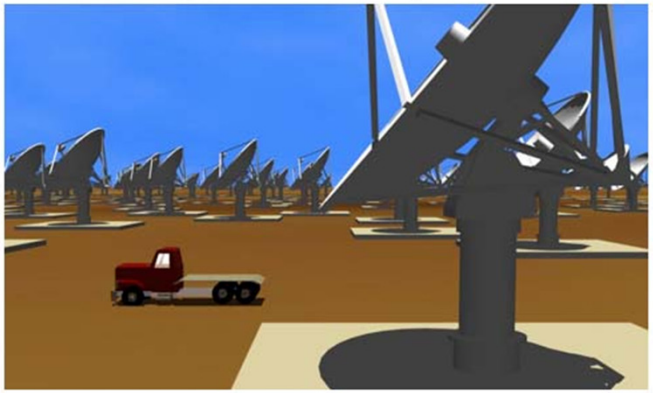
Space Flight Middleware: Remote AMS over DTN for Delay-Tolerant Messaging

Scott Burleigh
Jet Propulsion Laboratory, California Institute of Technology

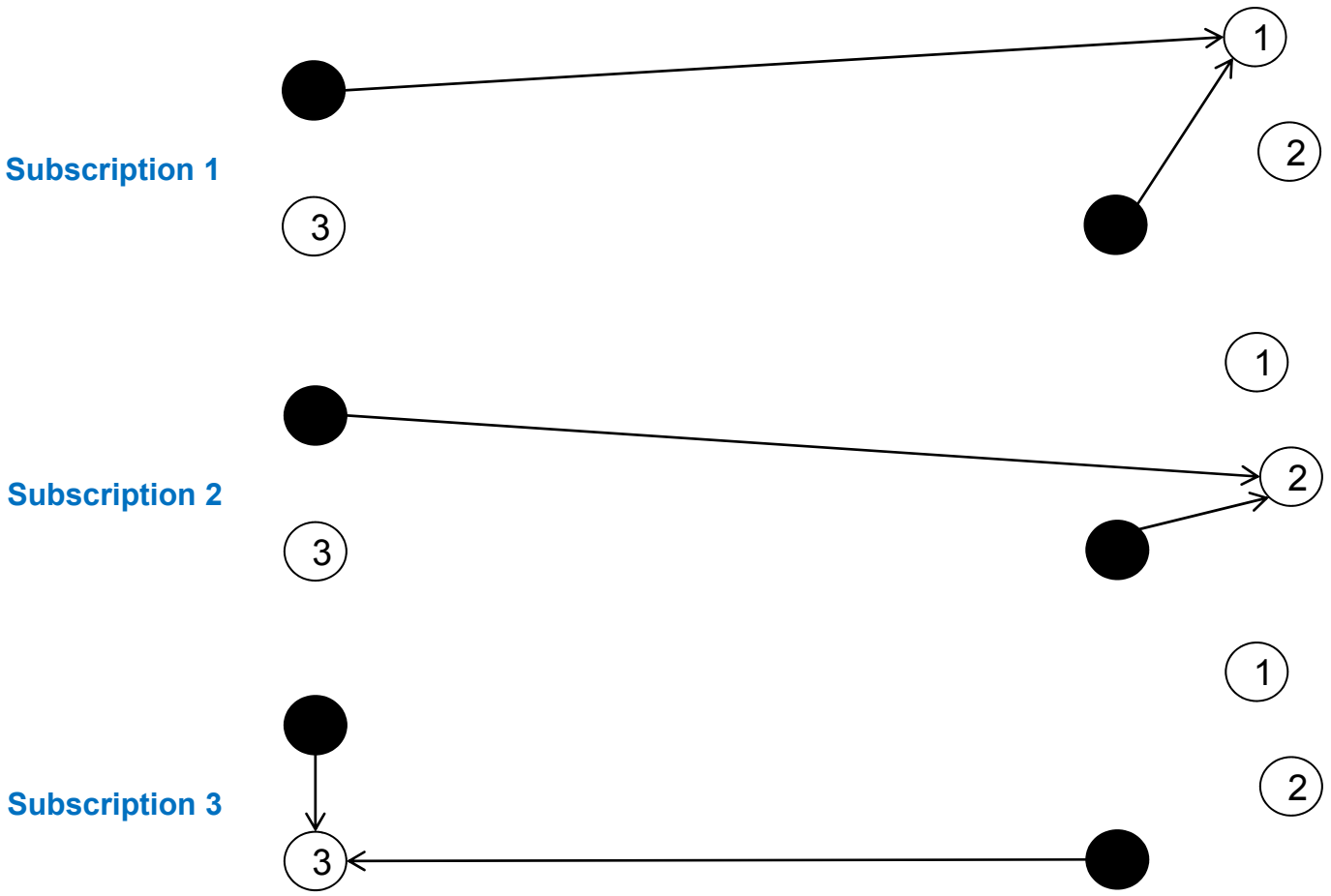

Space Flight Middleware Motivation

- Many military communication scenarios rely on multi-point data delivery. So do an increasing number of commercial Internet services.
- More generally, service-oriented architecture has been embraced by financial, commercial, and industrial network users.
  - Message-oriented middleware for multi-point data delivery can be seen as part of that architecture.
  - In particular, publish/subscribe ('message bus") functionality seems helpful.
- CCSDS is adopting the same communication concepts for flight mission communications.
- But current approaches aren't suitable for deep space missions.
  - No standards for scalable, reliable, multi-source multicast in the Internet.
  - Flight communications environment is even worse: punctuated connectivity, long signal propagation delays, high noise levels.
  - Delay-Tolerant Networking (DTN) mitigates these problems, but DTN multicast is challenging to implement: Bundle Protocol (BP) reliability is implemented by "custody transfer", but BP custody transfer was not designed to support a branching tree of custodians.

Space Flight Middleware
Delay-Tolerant Reliable Multicast

- **A proposed solution:**
  - **CCSDS Asynchronous Message Service (AMS) for multi-point delivery management.**
  - **Underlying remote AMS (RAMS) for scalability over a multicast distribution tree.**
  - **Further underlying Bundle Protocol (RFC 5050) for robust forwarding over a frequently partitioned network.**
  - **Further underlying Licklider Transmission Protocol (LTP; RFC 5326) for bandwidth-efficient retransmission-based recovery from data loss on noisy and intermittent links.**
- **Multiple layers of protocol, but each is well-documented in open literature and each has a well-defined role in the stack.**
- **It's a complex problem, and it's not surprising that the solution is complex, but layering helps make the complexity manageable.**

Space Flight Middleware



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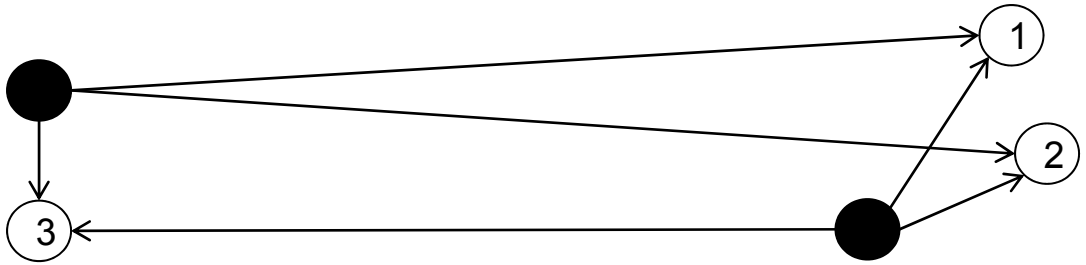

DTRM group

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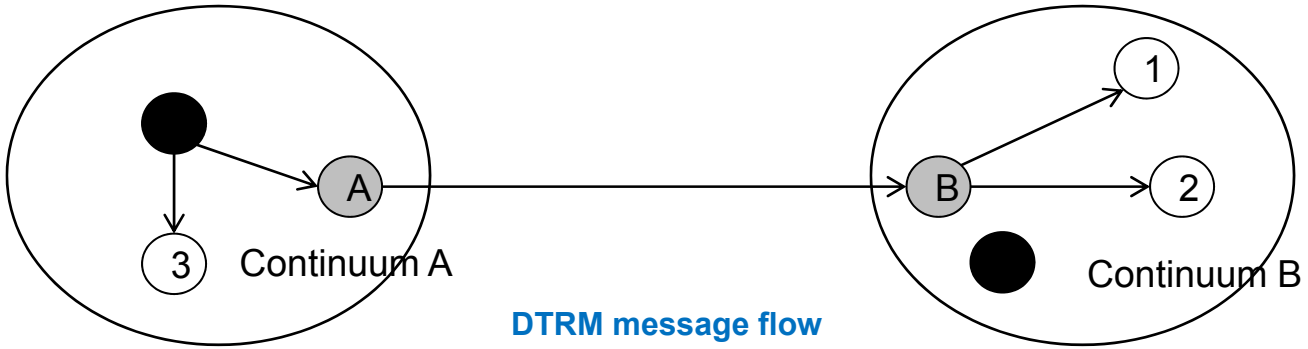

DTRM message flow

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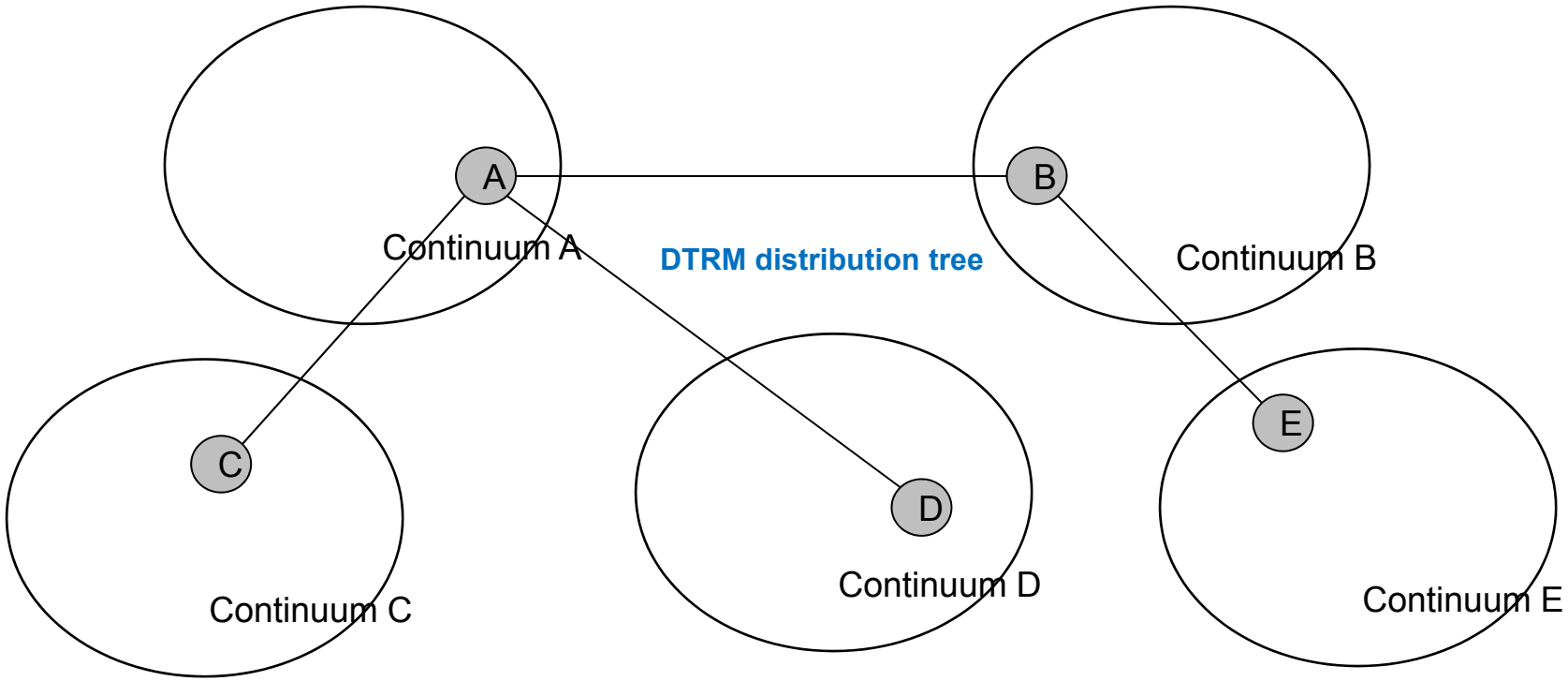

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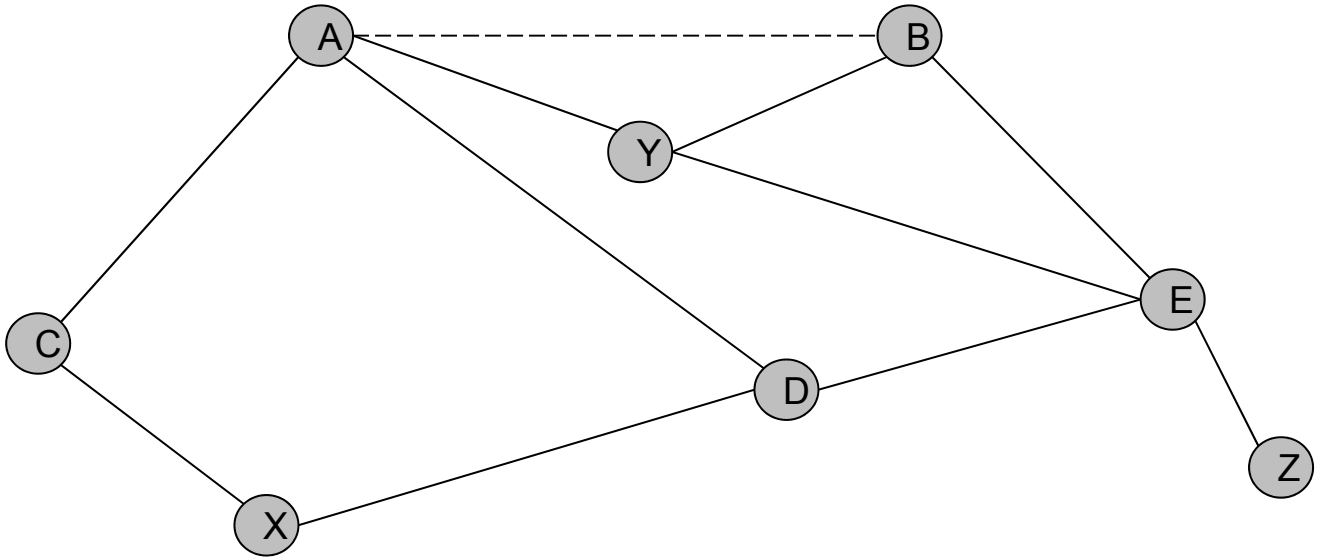
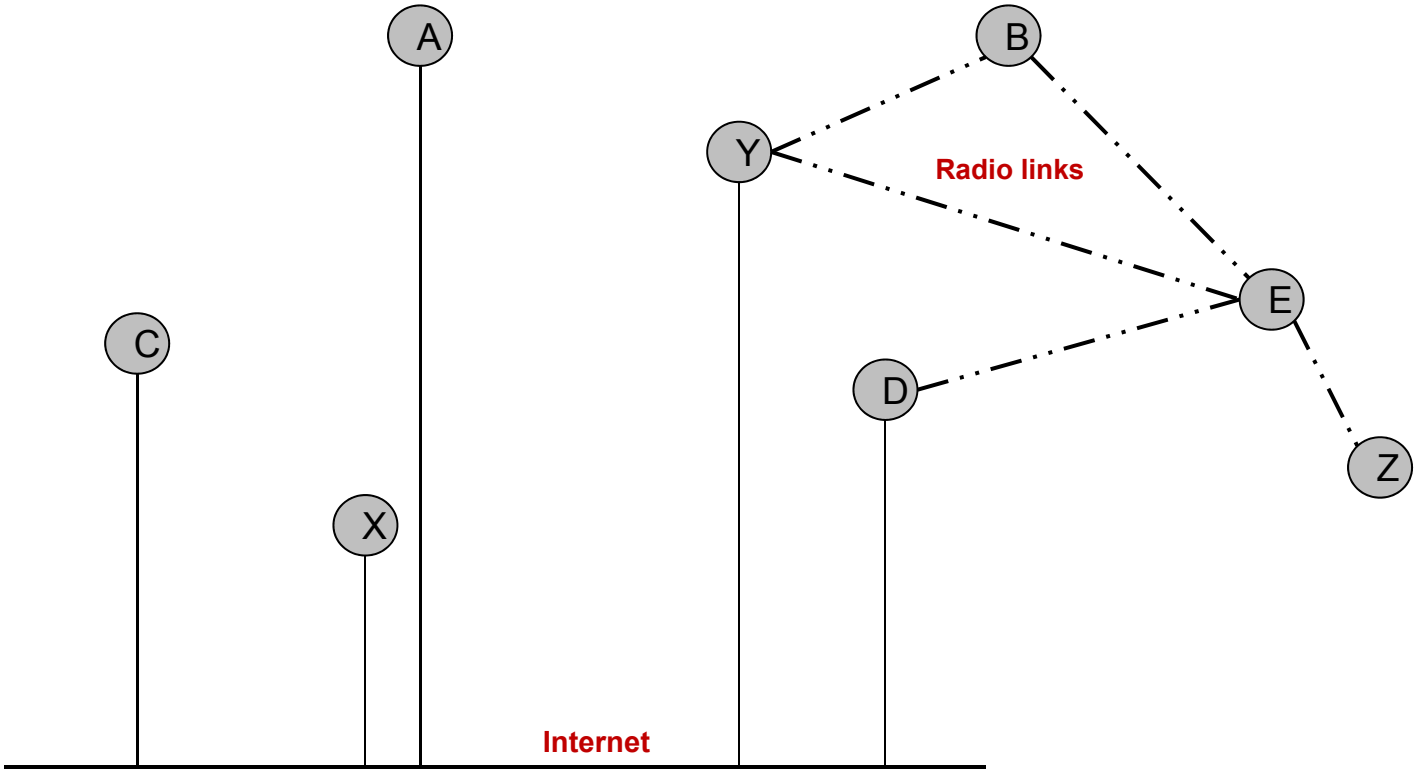
DTN mesh



Space Flight Middleware

Convergence-layer internets



Space Flight Middleware Architectural Advantage

- Conventional multicast – both IP and DTN – builds one multicast distribution tree for each multicast group (identified by a multicast address or multicast endpoint ID).
  - A change in the membership of the group can result in a change in the distribution tree, requiring propagation of multicast protocol messages.
  - Distribution tree has a single root (message source), to limit the complexity of tree management.
- DTRM enables an unlimited number of peer-to-peer groups to be overlaid on a single distribution tree.
  - Every member of every group can be a source of multicast messages.
  - Changes in the membership of a group never affect the topology of the distribution tree.
  - Entire new groups can be added at any time without propagation of any multicast protocol messages through the distribution tree.

Space Flight Middleware Implementation

- **Open-source implementations of all DTRM architecture components (AMS, RAMS, BP, LTP) are freely available.**
  - **The "ION" package at http://www.openchannelfoundation.org/projects/ION has an integrated distribution of the entire stack.**
- **Open specifications of all protocols in the stack are available for download at no cost.**
  - **RFC 5050 and 5326 are at www.ietf.org.**
  - **The AMS and RAMS specification will be published as a CCSDS Blue Book later this year. The draft Blue Book is available at www.ccsds.org.**
- **Initial testing of DTRM began in 2006.**
- **DTRM traffic first flowed over interplanetary space during the DINET experiment in October of 2008.**

Space Flight Middleware Conclusion

- **Assembling several well-defined open protocols into a properly configured stack seems to be a practical solution to the problem of providing messaging middleware for space flight applications.**
- **DTRM may have terrestrial utility as well. There currently aren't many standards-based, open-source solutions for scalable, reliable, disruption-tolerant, multi-source multicast.**